

ANGULAR DISTRIBUTION OF POWER FROM AN UNDULATOR AND A WIGGLER  
ON A 6-GeV STORAGE RING

There are two fundamental reasons to have a full knowledge of the angular distribution of power from an insertion device:

1. To evaluate the heat-load distribution on the first optical element in a beamline.
2. To estimate the total radiated power which will impinge on the walls of an insertion device. This is important to ensure needed cooling of the insertion device walls. The photodesorption is another closely related phenomenon determined by the exposure of the insertion device walls to the radiated power and of consequence to the successful operation of the storage ring.

We have discussed the angular distribution of power from a wiggler source in some detail in the past (LS-42, ANL-85-69). In here, we will primarily focus on undulators, but also consider situations as the value of K increases to the wiggler regime.

These calculations are very involved and cumbersome [1] and we shall only present some specific results related to the 6-GeV insertion devices.

The total power from an undulator is given by

$$P_T(\text{watts}) = 0.633 \ E^2(\text{GeV}^2) \ B_o^2(\text{T}^2) \ L(\text{m}) \ I(\text{mA}) \quad (1)$$

and its angular dependence is given by

L) is well under 5% if the aperture is  $0.26L$  mm. Thus for  $L=5m$ , the aperture must be larger than 1.3 mm. At five times this aperture (6.5mm) the power will be negligible.

Let us next consider a typical device. This hybrid REC undulator with  $K=0.63$  has its first harmonic at 15 keV. For this,  $L=5m$ ,  $N=263$ , Period=1.9cm,  $B_0=0.35T$ , gap=0.9 cm.,  $G(0.63)=0.875$ ,  $P_T = 1395$  watts,  $P(0,0) = 113$  kwatts/mrad<sup>2</sup>. Using the power distribution  $f_K(\psi,0)$  of Fig.1, we can estimate that the power is well under 5 kwatts/mrad<sup>2</sup> at an opening angle of 130 microradians. This amounts to only 5 milliwatts of integrated power over a square microradian solid angle. At the exit of the insertion chamber with say 8mm aperture, the power in a square microradian of the opening cone will be under 1 milliwatts, and the chamber walls will need no special cooling.

The other section  $f_K(0,\theta)$  of the power distribution (Fig. 2) is of lesser importance since the aperture in the horizontal plane is usually many times the vertical aperture. It is interesting to note however that as the value of  $K$  increases, the distribution approaches that of a wiggler with the power cutoff above  $\pm K/\gamma$ . Also with  $K=\infty$ ,  $G(K)=1.0$ , the Eq.(4) can be identified with Eq.(31) of ANL-85-69 describing the wiggler peak power  $P(0,0)$ .

All the above discussion is strictly true for a single positron trajectory. The finite size of the phase space of the positron beam in a storage ring will reduce the power at every point on the distribution. The distributions will also broaden by about 10 microradians in the vertical plane and by about 20 microns in the horizontal plane in a typical undulator. None of the above discussion will grossly change due to the finite size of the beam.

$$d^2P/d\theta d\psi \text{ (watts/mrad}^2\text{)} = 0.01084 E^4(\text{GeV}^4) B_o(T) I(\text{mA}) N G(K) f_K(\psi, \theta) \quad (2)$$

where E is the storage ring energy,  $B_o$  is the peak undulator field, I is the stored current, L is the undulator length with N periods, and

$$G(K) = (K^7 + 24K^5/7 + 4K^3 + 16K/7) / (1 + K^2)^{3.5} \quad (3)$$

and  $f_K(\psi, \theta)$  is complex integral normalized to 1. For  $\psi = 0$  and  $\theta = 0$ , the peak power per unit solid angle is given by

$$P(0,0) \text{ (watts/mrad}^2\text{)} = 0.01084 E^4 B_o I N G(K) \quad (4)$$

since  $f_K(0,0)=1.0$ . It is interesting note from Eq.(3) that much of the variation in  $G(K)$  is for values of K smaller than 1.0. Equation (3) yields,  $G(\infty)=1.0$  and  $G(1.0)=0.94$ . Hence the variation in the peak power  $P(0,0)$  for a given undulator increases as K approaches 1.0 and then saturates for larger values of K.

The two sections of the angular distribution, namely  $f_K(\psi, 0)$  and  $f_K(0, \theta)$ , representing the vertical and horizontal planes are shown in Figs. 1 and 2 for various values of K. The distribution  $f_K(\psi, 0)$  determines the exposure of the top and the bottom walls of the insertion device aperture. It should also be pointed out that this vertical section of the distribution for  $K=\infty$  is identical to that of a bending magnet given by Eq. (6) in ANL-85-69 and represented by Fig. 7 in that document. Thus the vertical opening of radiation power from any undulator or wiggler will be smaller than that from a bending magnet. If we now assume that the undulator source is located at  $L=0$ , for  $K = 1$  the deposited power at the exit of the insertion device chamber (at

In conclusion, it is argued that the insertion device walls need not be specially cooled on a 6-GeV ring so long as the aperture is kept larger than about 8mm. The photodesorption from the walls of an insertion device on a 6-GeV ring is likely to be of no major concern.

Reference:

1. Kwang Je Kim (to be published).



